Taking DALITE to the Next Level: What Have We Learned from a Web-Based Peer Instruction Application?

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Abstract: The Distributed Active Learning Interactive Technology Environment (DALITE) is a web-based tool designed on the principles of Peer Instruction. DALITE promotes student's self explanation and asynchronous explanation to others. This design-based research project involved practitioners and researchers in the co-design process. In this paper we describe the main features of DALITE, its extended system and its implementation. We report on its effectiveness as a tool for teaching and learning physics.

Introduction

A fundamental concern in science education, and physics in particular, continues to be the difficulty students experience building robust understandings of core principles and concepts along with their ability to use them in different settings – i.e., conceptual change and transfer of learning. Recent studies and practice-based efforts to address these problems tell us that science learning and teaching can benefit from pluralistic approaches (e.g., Treagust & Duit, 2008). These include changes to the ways students engage with the content and each other, the ways teachers orchestrate and use new pedagogical approaches, and the ways we design tools that support these various socio-cognitive and socio-cultural processes.

The Distributed Active Learning Interactive Technology Environment (DALITE) is a web-based tool that aims to promote conceptual learning while working within an asynchronous mode of student engagement. It involves the learners in a variety of tasks including writing explanations for conceptual questions, reflecting on and comparing these explanations to those of peers and experts, and taking part in the social construction of the database repository by voting on the most convincing explanations. It is part of a larger study and system of social constructivist pedagogical practices conceived to promote learning in physics at the postsecondary level. Its design draws on social conceptions of conceptual change, recognition of the role of context (e.g., Engle, 2006) and the success of the practical approach to conceptual learning called Peer Instruction (Mazur, 1997).

The study and evolution of DALITE is a design-based research (DBR) experiment (Hoadley, 2002). Its development team is made up of researchers and practitioners (college-level physics instructors) working together in using a co-design approach. DALITE is currently in its third iteration. In this paper we provide a brief background of the theoretical foundations of its design and features, including the extended system it has been embedded within (tagging and concept mapping activities). Additionally, we provide an evaluation of its effectiveness, to date, and speculate on its potential as a tool to support students' conceptual change as well as teachers' efforts to enact an active learning curriculum.

Background

Investigating how students learn physics has been a perennial concern not only of physics education research (PER) but also of the learning sciences (e.g., diSessa & Sherin, 1998). The body of research generated by both communities confirms that conceptions of the physical world, such as force, motion, and acceleration, are difficult to change with traditional instruction (e.g., Hestenes, 1992). However, studies of social constructivist instruction, popularly referred to as *active learning* pedagogy, report findings of statistically significant gains in students' conceptual understanding in physics and other science disciplines (Meltzer & Thornton, 2012). Of particular interest are implementations that focus on promoting conceptual change by placing an emphasis on intentional reflection (Sinatra & Pintrich 2003). Adding to this are questions about the processes involved in self-explanation (Chi, de Leeuw, Chiu & LaVancher, 1994) versus forms of peer explanations such as reciprocal teaching (Palincsar & Brown, 1984), and other collaborative and discursive practices (Stahl, 2006). In fact, it might be argued that there is value in examining the processes of what might be referred to as "interactive explanation" (Ploetzner, Dillenbourg, Preier & Traum, 1999). This interception between explaining to others, as well as reflecting on one's own explanation provides a power nexus for investigation. We propose that such a nexus is found in the variation on Peer Instruction that is at the heart of our designed intervention, DALITE.

Peer Instruction Approach to Learning

Peer Instruction (PI) is an example of an evidence-based pedagogical innovation popularized by Eric Mazur (Mazur, 1997). Its method of engaging students in scientific discourse focuses on acts of explanation, comparison, and reflection that lead to conceptual change. Meltzer (2013) states that, at the postsecondary level, PI is one of the most widely used active learning approaches in North America. No doubt in large part because of the growing body of research supporting claims of its efficacy in producing statistically significant conceptual gains (e.g., Crouch & Mazur, 2001).

In PI implementations, instructors present students with multiple-choice conceptual questions that the students answer using wireless handheld devices, colloquially referred to as *clickers*. These initial polling activities provide instructors with real-time feedback on the status of students' understanding. Answering these questions allows instructors to know whether or not concepts are known, somewhat known or unknown to students. If conceptual understanding falls within the "known" range (correctly answered by more than 70% of students), the teacher can move forward to another concepts and questions. If it is "unknown" (correctly answered by less than 30% of students), the teacher is advised to revisit the ideas. The real peer-to-peer interactions only come into play with the "somewhat known" concepts (30-70% correctly answered). When responses fall within this range, students are asked to turn to their neighbor and discuss their answers and reasoning. It is arguable that these discursive practices allow students to engage in sense making and intentional reflection on these specific concepts.

Some of the most successful implementations of PI have been those found in large lecture halls with hundreds of students. In such settings, rich discussions can arise because of the larger probabilities of having greater diversity among students, which undoubtedly acts to amplify the cognitive dissonance. However, in smaller classrooms there is often less diversity between students' answers and their understandings leading to a paucity of conceptual discussions. In such cases, PI has not always worked well. Adding to this, there is the question of what happens if we were to take PI online. How would it work if peers cannot interact in real-time? With growing interest in active learning pedagogies, which benefit from having students prepared ahead of class work – i.e., the flipped classrooms – there is added pressure on getting design elements for digital and online learning right.

Digital and Online Instruction of Physics

Computer supported learning environments to promote learning in physics is not new. A major initiative in this area is the Andes project, an intelligent tutoring system for a first year college-level physics course (Gertner, Conati & VanLehn 2000). It coaches students through the problem solving process step by step and provides hints should the student get stuck. Andes and similar tutoring systems are very successful and produce significant learning gains compared to traditional instruction. However, some have criticized Andes, and other similar tutoring systems, for failing to get at deep learning. In particular, three weaknesses have been identified as the failure to get students: (1) to use the language of the discipline (i.e., talk science); (2) to reflect more deeply on the learning; and, (3) to work on developing their conceptual knowledge (Graesser, VanLehn, Rosé, Jordan & Harter, 2001). Viewing these as challenges to be overcome when designing an online learning environment, we consider these as the foundation of our design features.

Building Collective Artifacts

Recent studies conducted by Slotta and colleagues show an increased sense of group regulation (aka agency) and collective responsibility when students contribute to commonly shared "knowledge base" resources (Slotta & Najafi, 2010). In addition it has long been shown that providing students with a sense of contribution has implications for promoting epistemic agency (Scardamalia & Bereiter, 2006).

Our Four Design Principles

In the process we can examine the four design principles we extracted from the literature: (1) promoting the use the language of the discipline (i.e., physics talk); (2) promoting reflections on explanations, one's own and that of others – i.e., the interactive explanation; (3) promoting deeper understandings of conceptual structure; and (4) promoting students' agency and responsibility for examining their peers' arguments and assessing their correctness and quality.

Methods

This project uses a design-based research (DBR) methodology. DBR allows for the design of tools or conceptual models that help us better understand the conditions under which the context and/or the intervention can promote better learning outcomes, and in turn, to adapt these to support better learning (Anderson & Shattuck, 2012). Data collected were for the purpose of informing us on the design principles related to promotion of conceptual understanding and conceptual change. Mixed-methods were used that include: standardized pre-post questionnaires (i.e., the Force Concept Inventory (FCI), Hestenes et al., 1992); and course grades. Qualitative data on student's conceptual understanding is documented in their DALITE rationales. Student interviews were conducted and include video recordings of think-aloud protocols that help to reveal how DALITE was used and how it was perceived as a tool to promote conceptual learning. Classroom observations were also collected to document the ways in which DALITE was used as part of the instructor's system of active learning practices.

Context and Participants

The study is situated within physics classrooms in three English-speaking colleges in Quebec. Four instructors participated and each of them was also a member of the research team (see Table 1). Student participants (N=168) were first year science majors, ages 17-19, enrolled in one of five sections of a 15-week introductory physics course – approximately equivalent to first-year university. DALITE was assigned weekly as homework via the web. Approximately four to five questions were assigned weekly along with other readings and problem-solving activity. DALITE was brought into the classroom setting regularly, which included having the instructor follow up with the correct answers and elaboration on questions that were identified as challenging. Additionally, it was made part of an extended activity that involved concept mapping and tagging activities. These will be discussed only briefly.

Table 1: Number of instructors and students participating in the study.

	College X	College Y	College Z
# of Instructors	n=1; 2 sections	n=1; 1 section	n=2; 1 section each
# students	n=30 and n=31	n=30	n=36; n=41
Classroom design	Active Learning classroom	Active Learning classroom	Hybrid classrooms

Designing DALITE

DALITE was conceived as a way to harness the benefits of PI and address some missed opportunities. In traditional enactments of PI, student conversations disappear into the ether. Though instructors sometimes overhear conversations, there is no trace left behind. More importantly, instructors seldom know what types of arguments and reasoning are convincing to students. What discursive elements help students change their answers – whether they change towards or away from the correct answer. In addition, there is little documentation of the accumulated database of conceptual questions, and what can be learned from how they are responded to. In short, how the question frames the context. Might there be different effects regarding the timing of assigning questions, might there be an issue of the context of delivery or the wording. Can we promote better forms of *intercontextualization* with the sequencing and design of questions? DALITE as a solution provides students with a diversity of explanations for all the possible answer choices. It allows students to interact with rationales from students at different institutions or even "peers" who took the class previously.

The DALITE infrastructure is made up of the following components: (1) a student registration and software application management; (2) a framework for data mining and tracking of student interactions in real time including the instructional scripts; (3) a central database or repository; and (4) data displays for instructors. The platform uses "Agile" development practices with the aim of ensuring future availability, scalability, and performance. The database repository is composed of two parts: (1) the curriculum content – conceptual multiple-choice questions (sometimes referred to as *concept test* questions); and, (2) the student-generated answers and rationales for these answers.

To date, the curriculum database contains over 120 questions spread across the three main topics generally covered in an introductory physics course – i.e., kinematics, dynamics, and energy and momentum. These questions are designed to be roughly at the first-year university level. Influenced by the Ohio State concept test questions (Lee, Ding, Reay, & Bao, 2011), many questions are organized into sets of three to four questions on a single concept that progressively increase in difficulty. These sets of increasingly difficult multiple-choice problems are built on similar deep structures with different surface features, or similar surface features with different deep structures. Instructors have control over the selection and assignment of questions using a specially designed teacher portal. Each problem set can be customized to meet the perceived knowledge level of the students.

The second database repository, the student-generated rationales, has been developed through a "seeding" process. That is, the database asks about 20 students to answer the questions and write rationales, without working through the full DALITE script. This process enables the first participants in the system to see other students' rationales. However, it places constraints on the development of new questions entering the system. In addition, because rationales are student-generated we believe it necessary to develop a mechanism of cleaning up and categorizing the database. This has lead to the implementation of a voting system – students have the option of giving a "thumbs up" to the rationale that convinced them. In doing so, these ratings are a design element. In the future a heuristic will be designed to highlight these popular rationales. Lastly, nonsense rationales will be eliminated (e.g., unreadable text, meaningless strings of symbols).

Lastly, the data display for instructors brings DALITE into the classroom. The display provides an interface to allow the instructor to review students' progress in real-time as well as provide a tool for in-class review. It has proven to be more important than we had thought. We discuss this in the upcoming section.

DALITE Scripts: How Does It Work?

The script for DALITE mirrors much of what we imagine students do when they engage in the discursive practices of PI. As such, the DALITE script consist of the following six steps: (S)elect multiple choice answer; (W)rite rationale; (R)econsider based on alternatives; (R)evote; (V)ote on most convincing; and (R)eview expert rationale. In step 1, students are presented with a multiple-choice conceptual question. They are asked to select an answer from the multiple choices. In step 2, they then write an explanation for their choice, what we call rationales. In step 3, they are asked to reconsider their answer based on another possible alternative, the aim is to replicate the experience of the "turn to your neighbor" phase in PI. If their answer is incorrect, they are presented with student rationales for the correct answer as well as rationales from other students on the same incorrect answer they chose. The aim of this comparison is to present the contrast and cognitive dissonance of traditional PI. If their answer is correct, they are presented with rationales from other students on the same correct answer as well as student rationales for the most popular wrong answer; the aim of this comparison is to test for fragile understanding or lucky guessing. In step 4, the student is asked to consider whether one of the rationales was particularly convincing, if yes they are asked to vote it "thumbs up". In step 5, students are asked to re-choose an answer for the original question: either their original answer, or the other answer that was just presented to them, based on the reading of these rationales. Lastly, step 6, they are presented with a normative rationale of an expert, but are not given "the" answer; the aim of this decision being to delay feedback and increase self-regulation of criteria and standards.

Other Features Designed to Extend the DALITE System

In addition to the online components, we consider DALITE to be embedded into an extended system that includes a Tagging and a Concept Mapping tool. The tagging tool is digital and paperbased. It is designed to prompt students' thinking about the deep structure of the content contained in the DALITE questions. As such, this tagging tool takes students through a series of cascading concepts – from general to specific. It starts with a DALITE question, then asks the students to reflect on and identify/tag key concepts, first individually, then collaboratively in small groups.

The concept mapping tool is computer-based, and presently uses C-Map (citation). It takes the opposite approach to the tagging tool. It starts by asking students to work collaboratively to identify connections and state relationships between a restricted set of concepts – in the process creating a concept map. It then asks students to add in the DALITE questions to the appropriate area of the map. At the end of this process, students are asked to work on the maps individually, as a reflection exercise.

These tools were implemented separately. Two section worked with the tagging tool (College X). Meanwhile another two sections worked with the concept mapping tool (one section at each College Y & Z). In all instances students were asked to write rationales for the DALITE questions after the activity.

Building on DALITE's Implementation

DALITE implementation over the five sections of 168 students produced approximately 7182 student-generated rationales. The actual distribution by college is described below (see Table 2). These variations in the number of DALITE questions assigned, with the respective variations in the number of rationales written, allowed us to examine the impact of these different modes of implementation. Results also show a statistical difference between DALITE students (average mean Hake gain = 0.49) compared to non-DALITE comparison group (mean = 0.31). Interestingly, the FCI gains for students in these five sections are near identical (0.59). These gains are calculated as the number of transitions of wrong to right answers divided by those that were initially wrong. These results suggest that using DALITE for conceptual gains may not be dependent on the quantity of questions but more likely the choice of questions – i.e., the difficulty and timing (pre-post instruction).

Table 2: Descriptive statistics on the rationales generated by students in the five sections, across the 3 colleges.

# Rationales written/ student	College X_1	College X_2	College Y	College Z_1	College Z_2
Mean	51	56	36	40	34
Mode	58	66	48	50	48
Median	56	63	39	45	36

Discussion

In regards to the four design features described earlier: (1) The DALITE rationales show that students have been moving towards identifying what we consider the "trigger feature" when explaining their answers. The trajectory of their rationales also shows more complete explanations over time. In doing so, these data suggest that the design of repeatedly asking for rationales can promote improved use of physics talk. (2) Our think-aloud protocols and interviews with students show that they have a high level of metacognitive activity when using and discussing their use of DALITE. In fact, one surprising finding is that the young women (?) spent considerably more time reflecting on their explanations. One student, whose first language was not English, stated that the reading of rationales has taught her how to better read and understand physics explanations on the internet, which are frequently in English. 3) Observations of students' tagging activity as well as their interviews suggest that the combined use of DALITE and tagging have promoted their understanding of the deeper, structural similarities between questions, regardless of the surface features. Subsequent assessment activities, referred to as "sorting tasks" show that these students are better able to identify similarities between questions compared counterparts who have not used the DALITE system.

The instructor display of student results has proven to be a very important feature of DALITE. Arguably, it the most practical tool for instructors. It provides immediate and detailed feedback to instructors and greatly supports the flipped classroom method or active learning approach in general. Students are better prepared for class and teachers can identify conceptual issues before class and tailor their class to focus on these specific issues. Also it allows students to focus on both the collective and the individual – what does the class know, what do specific individuals need to know (where are they falling short), a feature we only identified in student interviews.

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